



National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology



Verification & Validation on OCO-3: A case study of V&V for ISS missions

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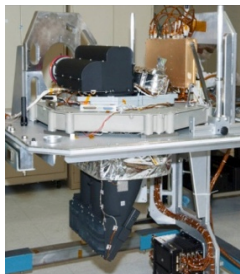


Agenda:

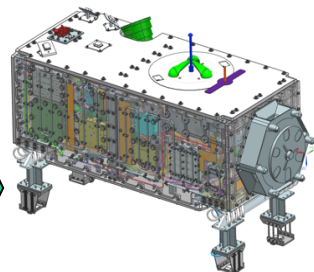
- OCO-3 Mission Architecture
- OCO-3 Observation & Science Modes
- OCO-3 Science Overview
- OCO-3 V&V Program Goals & Scope
- OCO-3 Verification Approach
- OCO-3 Requirement Tree
- OCO-3 System/Subsystem Project Level V&V Flow
- ISS Verification Process
- Merging OCO-3 V&V with ISS V&V
- OCO-3 ISS Verification Summary
- OCO-3 Next steps

OCO-3 Mission Architecture

Spare OCO-2 Instrument



OCO-3 Payload



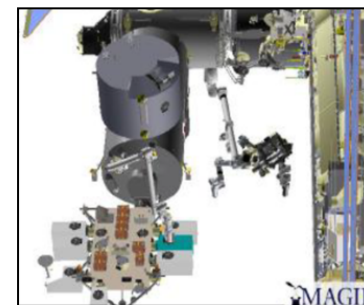
SpaceX Dragon Transfer Vehicle



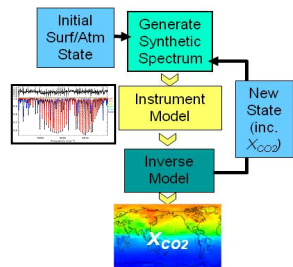
Falcon-9 LV



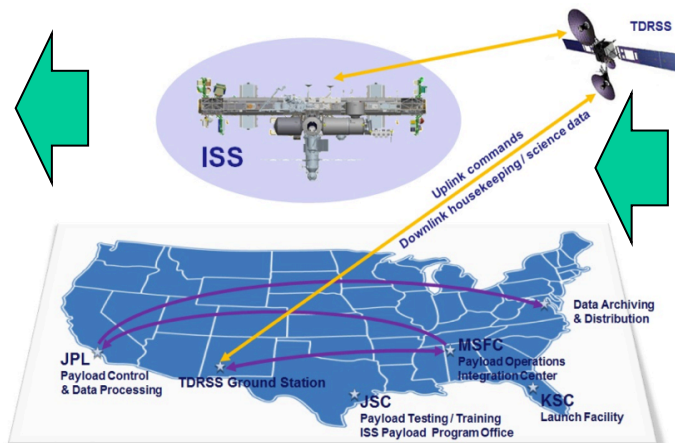
Installation on ISS JEM-EF



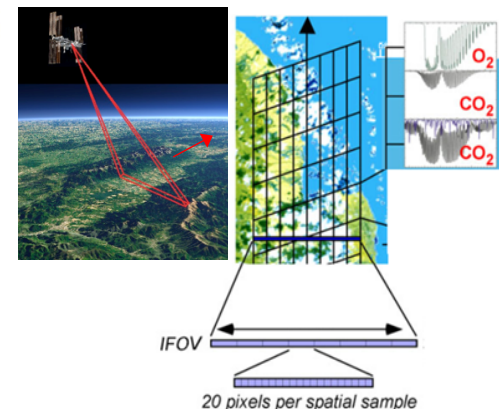
Science Data Processing



Command and Data Flow

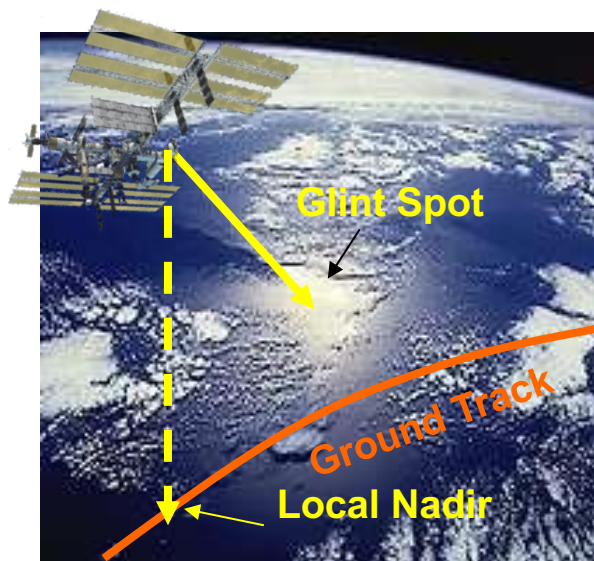


Science Data Collection



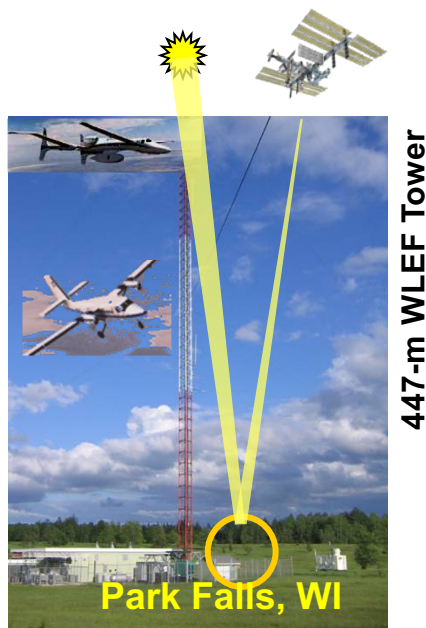
Nadir/Glint Observations:

- Nominal science measurements
- Nadir over land, glint over ocean during daylight → more data collected than OCO-2



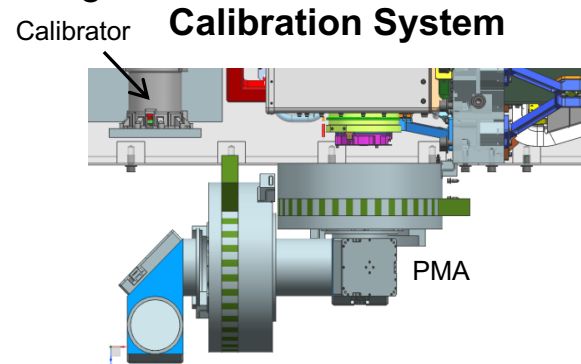
Target/ Area map Observations:

- Validation over ground based FTS sites, field campaigns, other targets
- Snapshot map variant for area mapping

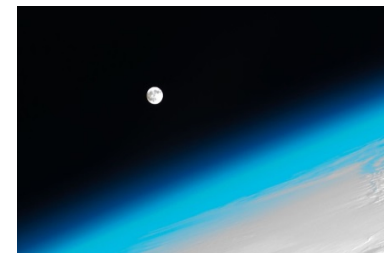


Calibration Measurements:

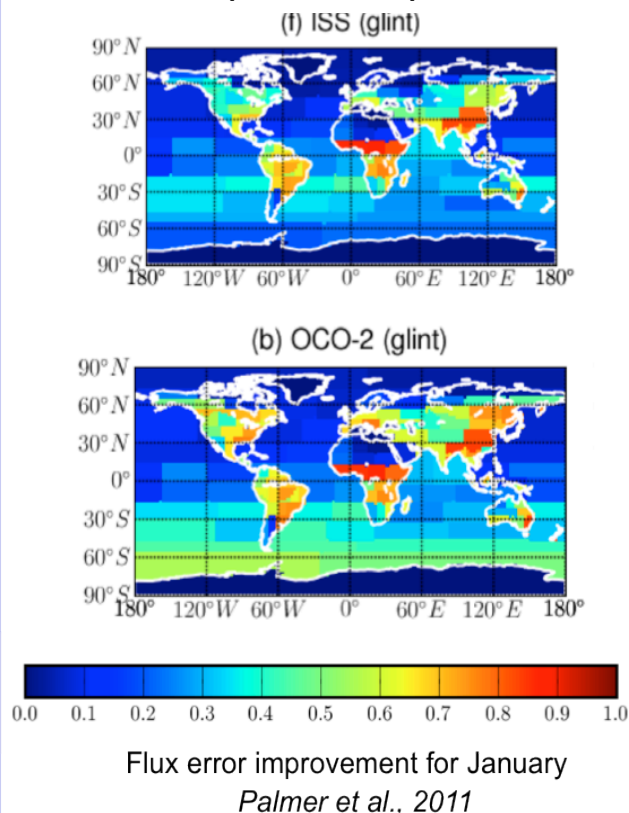
- Dark and calibrator measurements for radiometric calibration
- Lunar calibration goal for geometric calibration



Lunar view from ISS



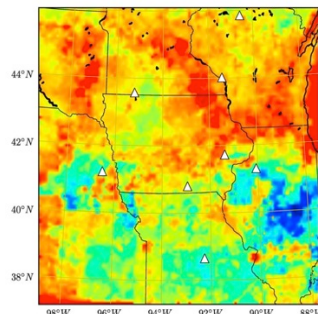
Global Flux Estimates: OCO-2 and OCO-3 impacts (simulated)



Unique Science Opportunities with OCO-3

Terrestrial Carbon Cycle

Process studies enabled by measurements at all sunlit hours, including SIF. ISS will contain complementary instrumentation.



Midwest Carbon Flux
From Schuh et al., 2013

Anthropogenic Emissions

Enabled by enhanced target mode using pointing mirror assembly





OCO-3 V&V Program Goals & Scope



Goals:

- To verify that the OCO-3 instrument meets performance requirements and validate the mission implementation approach
- To verify that OCO-3 will survive and operate through the expected environments from launch through end of mission life
- Provide the Project, Partners (ISSP and JAXA), and Launch Service Provider (SpaceX) with confidence in the flight interfaces by verifying interface requirements specified in ICDs signed with each organization

Scope:

- The V&V program includes L2 Project System through L4 subsystem requirement modules
- While it is common for projects to have a separate MOS V&V program, OCO-3's V&V program encompasses all payload, interface, and MOS requirement modules



OCO-3 Verification Approach



❖ Verification matrix captured in DOORS

- For each requirement, matrix now identifies:
 - Rationale & detailed verification comments
 - Verification approach
 - Verification Status
 - Any related ECRs or Waivers
 - Link to verification reports and/or short descriptions of methods of verification
 - Provides the evidence or summary of how requirement was closed

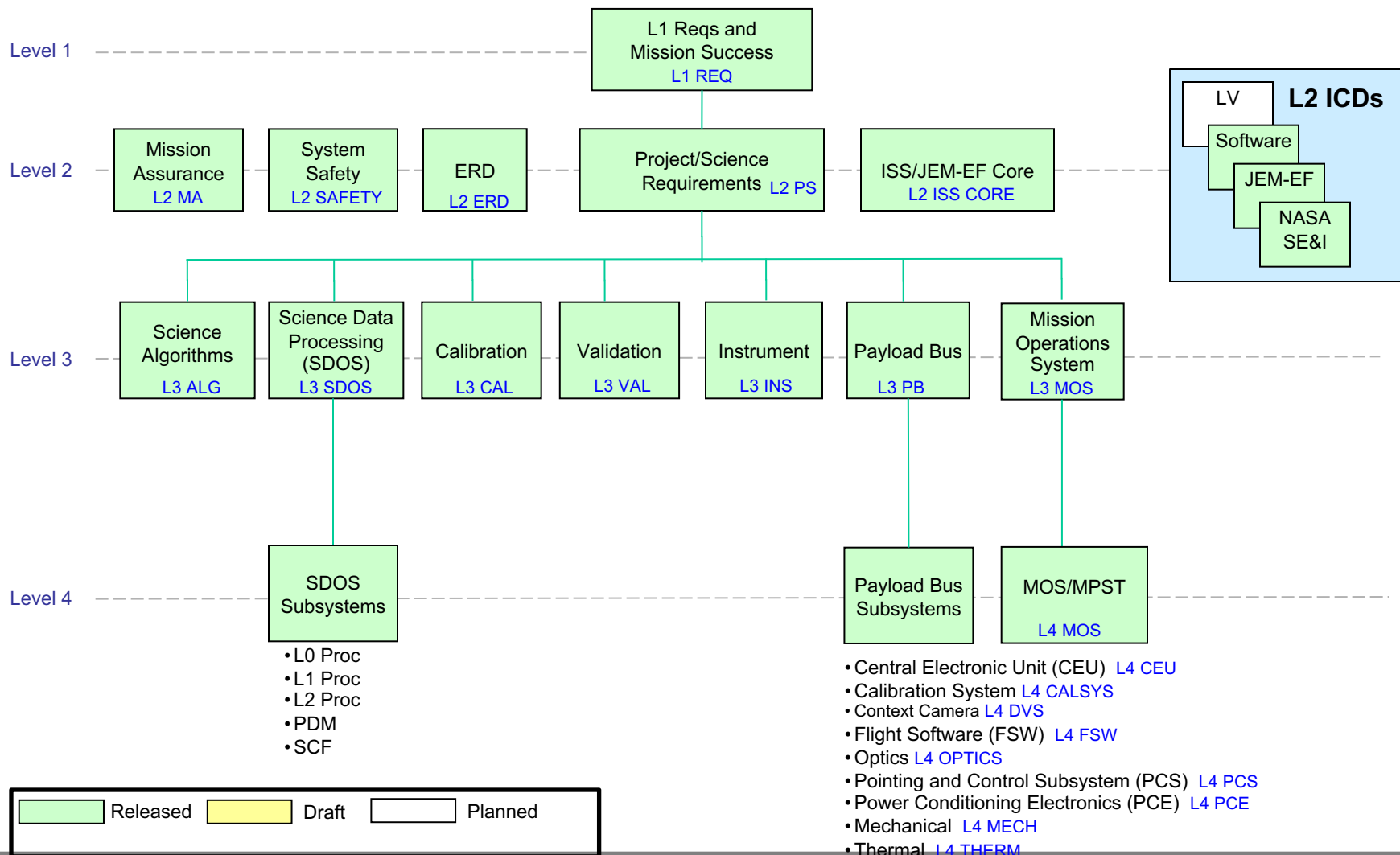
❖ Requirement verification is reviewed during every test but final verification of the requirement is determined by the final test, TVAC-2.

❖ Augmented version of OCO-2 V&V

- Improvements include:
 - No non-JPL modules
 - Simplified report generation
 - Leverage the vast amount of existing procedures that exists as well as the experiences of the people who participated in the V&V of OCO & OCO-2



OCO-3 Requirement Tree

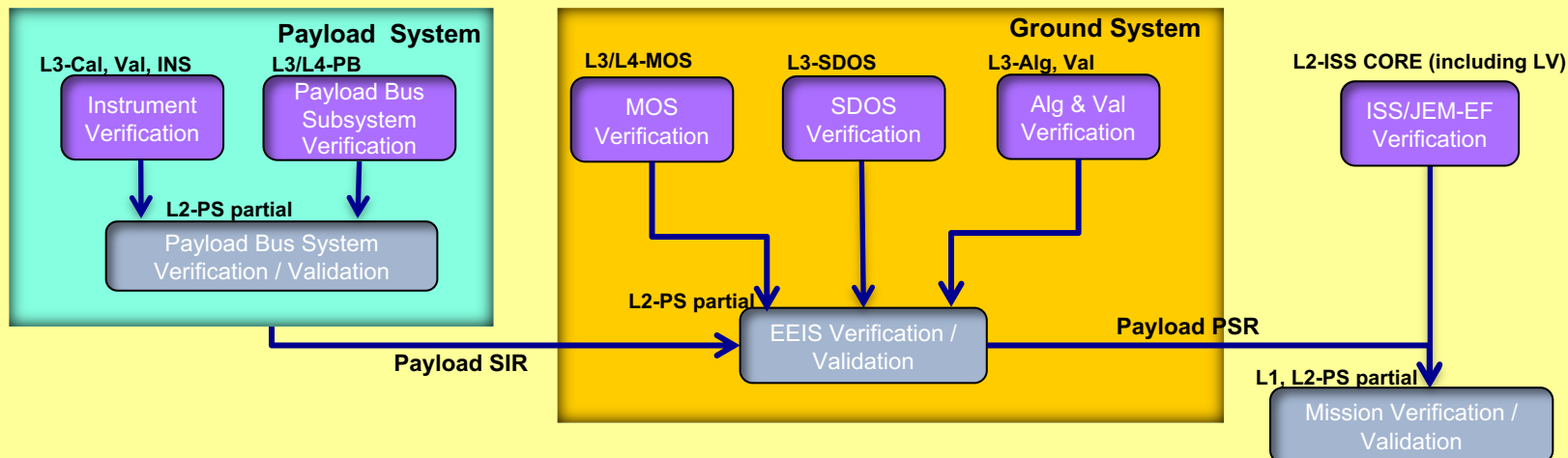




OCO-3 System/Subsystem Project Level V&V Flow



Project V&V - L1 & L2

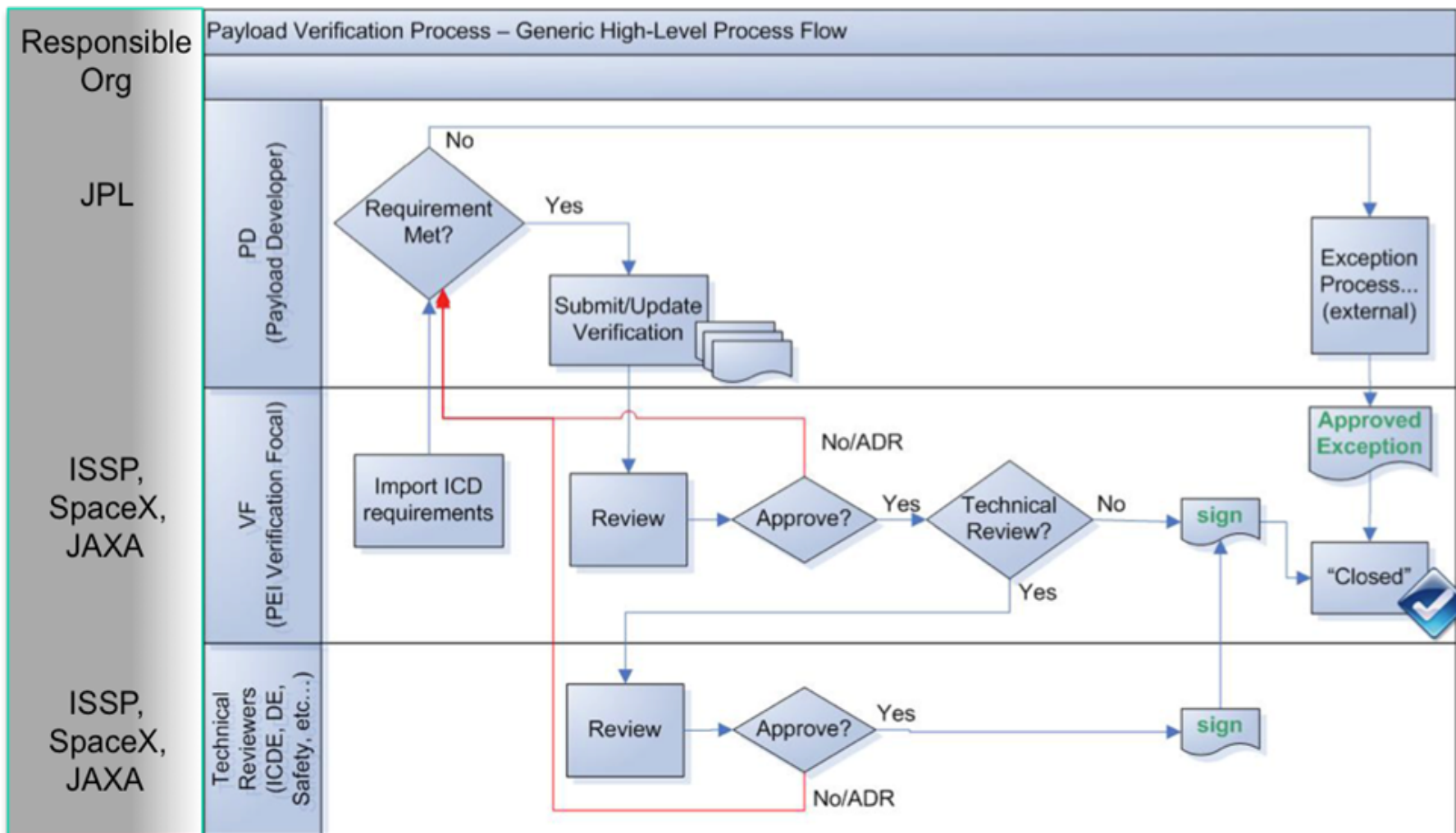


❖ The V&V Process Includes

- Verification Activities
 - Project V&V Engineer is responsible for supporting the PSE in closure of all L1 & L2 requirements
 - Individual Level 3 and Level 4 elements before Payload Bus Integration, (L4 PB, Instrument, SDOS, etc)
 - Ground System Verification (MOS, SDOS, L2)
 - Science Verification (Alg, Cal, Val)
- Validation Activities
 - Component Validation
 - Mission Scenario Tests (MST)
 - ORT/Rehearsals – 3 Planned
 - EEIS Testing (Combination of RF Compatibility and Data Flow Testing)



ISS Verification Process



ADR = Additional Data Required



Merging OCO-3 V&V with ISS V&V



ISS Requirement Idiosyncrasies

1. The process for negotiation of a change in these requirements is longer than that of a typical project held requirement.
2. The verification approach and methods are predefined by the external entity.
3. And, the process for accepting the closure of these requirements is called out specifically by the ISS program and not negotiable.

OCO-3 Workarounds

1. To treat these requirements as level 2 requirements but to treat the verification of these requirements as a separate process.
2. To have the official audit of these requirements be done by the expert ISS engineer, but to close the requirements in the JPL system as soon as the requirement was considered verified by the OCO-3 ISS engineer.
3. To ensure that ISS/JAXA/SpaceX requirements for each subsystem are closed prior to delivery to I&T.

- Lessons learned from OPALS
 - ISS constantly changes requirements in the form of “PIRNS” (their version of ECRs)
 - All requirement verifications are tracked by ISS system (VERITAS)
 - PIRNS are not captured in VERITAS and the ICD is not rev'd when changes occur → no way to track these changes
 - OCO-3 took the approach of capturing all requirements in 1 DOORS module which can easily attach applicable PIRNS and update object text and/or verification as needed so it's always up to date
- ISSP did take into account lessons learned from OPALS and other payloads and remodeled their entire ISS payload structure and updated their documents (called RISE)
 - Since this new RISE effort, very few PIRNS have been release against OCO-3
 - Total # of requirements was reduced
 - Requirements were re-written to be more clear based on lessons learned
 - VERITAS updates and tracking of requirement changes is still lagging/slow
- Future PDs should follow a similar approach and track all ISSP and LV in DOORS



Figure 3.1.3.1.2-1 OCO-3 Coordinate System
 (Page 3.1.3.1.2-1, 1/10/2014, 10:00 AM, 10/1/14)

Req ID	Req Type	Req Text	Req Status	Req Category	Req Priority	Req Date	Req Author	Req Reviewer	Req Approved	Req Comments
401	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
402	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
403	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
404	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
405	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
406	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
407	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
408	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
409	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
410	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
411	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	
412	Functional	The ISS shall provide a stable platform for the OCO-3 instrument.	Open	Functional	High	10/1/14	JPL	CS	CS	

DOORS: ISS Module for
 ISS/JAXA/SpaceX
 Requirements



OCO-3 Next steps



- OCO-3 is about to start Thermal Vacuum Testing
- Then we will put the OCO-3 payload into a planned storage
- We will continue with validation testing until Launch
- Launch Date is currently set for Feb 1st 2019 on SpaceX 17